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ORIGINAL ARTICLE

Role of magnetic resonance venography in assessment of intra-thoracic central veins in hemodialysis patients

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KEYWORDS

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Abstract *Aim:* To determine diagnostic accuracy of magnetic resonance venography (MRV) in assessment of the patency and steno-occlusive disease of intrathoracic central veins in hemodialysis patients.
Patients and methods: Between February 2013 and December 2014, 40 hemodialysis patients with suspected intrathoracic central venous stenosis were examined by MRV (phase contrast in 35 patients and contrast enhanced in 5 uncooperative patients). Digital subtraction venography (DSV) was done in the 40 patients and used as the standard reference. The results of MRV were compared with those of DSV. Kappa index with percent agreement between 2 methods was calculated.
Results: The results showed excellent agreement as MRV detected 140 out of 141 patent, and all 36 stenotic and 62 out of 64 occluded segments of intra-thoracic central veins with k were 1.00, 1.00 and 0.97 and P value = <0.001, 0.001 and 0.023 respectively. MRV had 98.6% sensitivity, 100% specificity and 99.3% accuracy in diagnosis of patency and stenoocclusive disease of central veins.
Conclusion: MRV is a highly sensitive technique in the diagnosis of patency and steno-occlusive disease of intrathoracic central veins and may be used as an alternative to DSV for the abnormalities of central veins in hemodialysis patients.

1. Introduction

A common and significant problem in the management of hemodialysis patients is central venous steno-occlusive disease (CVSD), the incidence of which has been reported in the literature to be in the range of 25–40% (1). This can result in the loss of the access site, increased venous pressure on the dialysis machine leading to its stoppage, and arm swelling due to venous hypertension. Prompt treatment should be required (2).

The cause of central vein stenosis used to be iatrogenic; due to repeated insertion of dialysis catheters in the same vein over long period; and also the repeated infection that occurs at the tip of the catheter (3).

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The diagnosis of central venous stenosis is made based on both clinical and imaging findings. Digital subtraction contrast venography is the current reference standard (4). Ultrasonography has been widely used for the detection of CVSD, but it can only diagnose stenosis in internal jugular vein and subclavian vein and cannot detect stenotic lesions in other central veins such as brachiocephalic veins and superior vena cava (SVC) (5).

Magnetic resonance venography (MRV) shows to be more accurate and reliable than ultrasonography in diagnosis of CVSD, as the images obtained from MRV show better morphological findings detecting the length and degree of the lesions (4), which indicate whether interventional procedures are necessary and can identify the length of the lesion that requires crossing with the catheter and guide wire (2).

MRV can be done by contrast and noncontrast techniques. Noncontrast MRV using Time of Flight (TOF) and phase contrast (PC) techniques allows noninvasive visualization of the venous structures (6). Contrast enhanced MRV can also be done safely with using small dose of contrast such as gadoterate meglumine (Dotarem; Guerbet; Villepinte, France) instead of gadopentetate dimeglumine (Magnevist, Schering, Berlin, Germany). This contrast proved to be more safe in patients with renal impairment and less likely to induce nephrogenic systemic fibrosis (NSF) (7,8).

2. Aim of the work

To determine the diagnostic accuracy of phase contrast and three-dimensional gadolinium-enhanced magnetic resonance venography (3D-Gd-MRV) in assessment of patency and steno-occlusive disease of intrathoracic central veins in hemodialysis patients.

3. Patients and methods

3.1. Patients

During the period from February 2013 to December 2014, this study was conducted in the Radiology Department of Mansoura University Hospitals (MRI unit and Emergency Hospital). At first 45 patients were enrolled but five of them were excluded due to contraindications to examination; three Patients were with metallic prosthesis, one cardiac patient with pacemaker and one patient had claustrophobia. So, finally, 40 patients were included, and their age ranged from 25 to 70 years with mean age of 47.5 years. Inclusion criterion was hemodialysis patients with suspected intrathoracic central venous stenosis referred to us from the vascular surgery department. All patients had a history of previous catheterization in the internal jugular and/or the subclavian veins. 15 patients had manifestations of venous hypertension (all presented with arm swelling and 4 of them had associated facial swelling).

All participated patients signed the informed consents required by the Human Study Committee (see Figs. 1–5).

3.2. Methods

Phase contrast MRV was done in 35 patients and gadolinium-enhanced in 5 uncooperative patients for diagnosis of patency and stenoocclusive disease of intrathoracic central veins in hemodialysis patients. Digital subtraction venography was done in all the 40 patients and used as the gold standard reference.

Fig. 1 Phase contrast MRV of a female patient aged 35 years (control group). 3D reformate of phase contrast MRV showed patent central veins.

MRI examination performed on a 1.5-T unit (Ingenia; Philips Medical Systems, Best, the Netherlands) using a torso phased-array coil centered over the thoracic inlet. The field of view (FOV) covered the region from above the clavicle to the diaphragm in craniocaudal extension and the whole chest in axial diameter.

3.2.1. Acquisitions of MRV

MRV was done by phase contrast (PC) technique in 35 patients. Phase contrast technique is a gradient echo technique with TR 8.0 ms; TE 4.5 ms; flip angle 15°; FOV 300 mm; Venc 20 cm/s; total scan time 6 min and 36 s. The remaining 5 patients of the diseased group were critically ill and cannot withstand the long time examination of phase contrast technique, so, MRV examinations were conducted using the contrast enhanced (CE) technique, as, gadolinium-based contrast material (Dotarem; Guerbet; Villepinte, France) was administered as a bolus injection at a weight adjusted dose (0.2 mmol/kg). 3D Dotarem enhanced MRV was performed during end-inspiratory breath-holding in the arterial phase and then in the venous phase of the central chest veins. A fixed delay of 20 s between both acquisitions was set, allowing the patient to breath in between. All injections were administered with flow rate of 2 mL/s and a 20 mL of normal saline solution was flushed through a 22-gauge injection cannula placed in peripheral vein. 3D data sets were acquired in the coronal plane using a spoiled GRE sequence with TR 4.6 ms; TE 1.8 ms; flip angle 30°; FOV (maximum, 500 mm); matrix 200–512; 1 excitation; bandwidth 390 Hz/pixel; and time of acquisition 23 s. Immediately after examination, a hemodialysis session was arranged to each case, observed for 24 h for

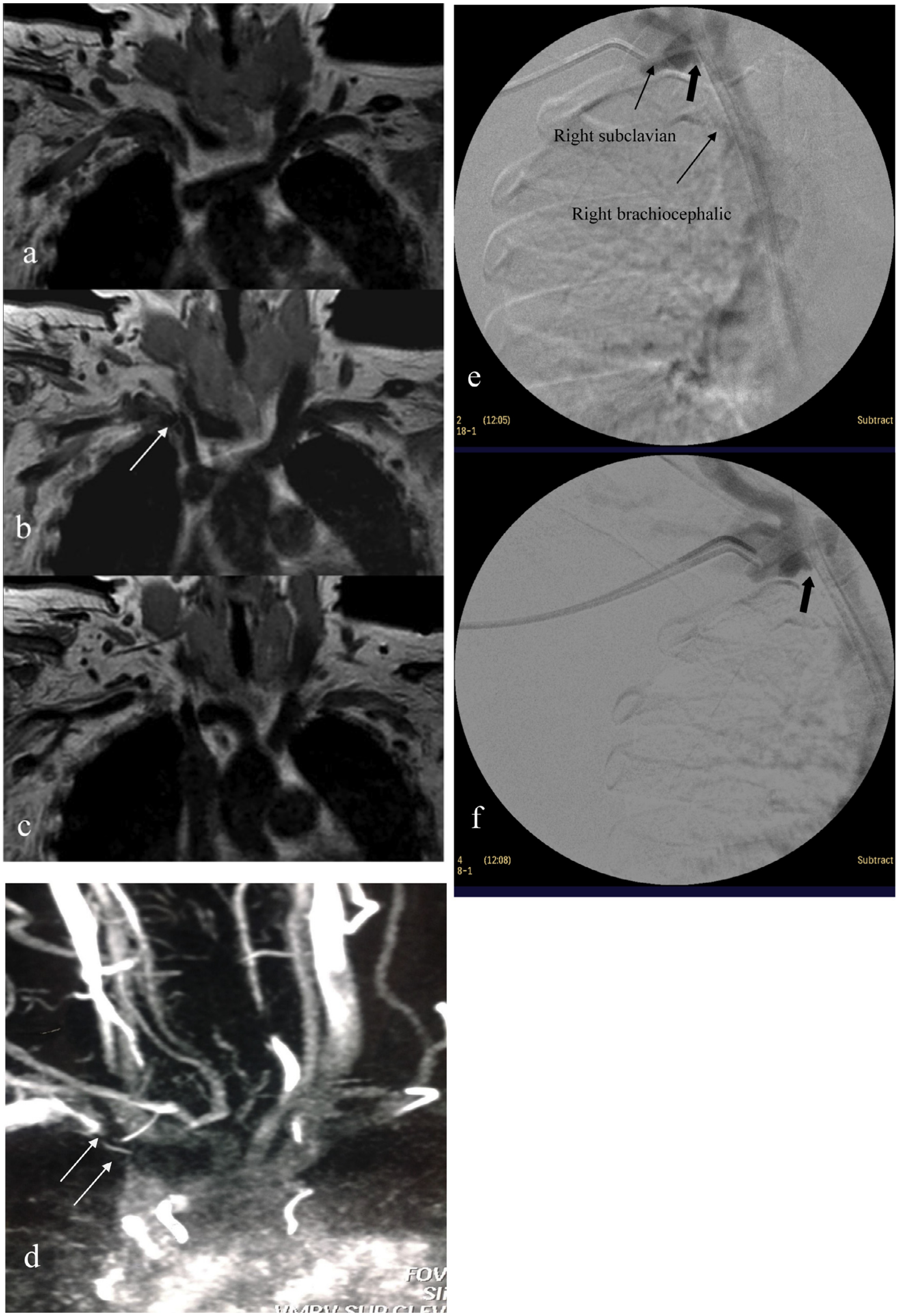

Fig. 2 (a–c) Source image of phase contrast MRV. Findings: patent left subclavian, brachiocephalic and internal jugular veins (a). Occluded segment at the end of right subclavian vein (white arrow) (b). Patent SVC (c). 3D reformatted phase contrast MRV shows segment of total occlusion at proximal end of RT subclavian vein with severe stenosis of RT brachiocephalic vein (white arrows) (d). (e and f) DSV images. Findings: total occlusion at the end of right subclavian (thick arrow). Attenuated right brachiocephalic vein.

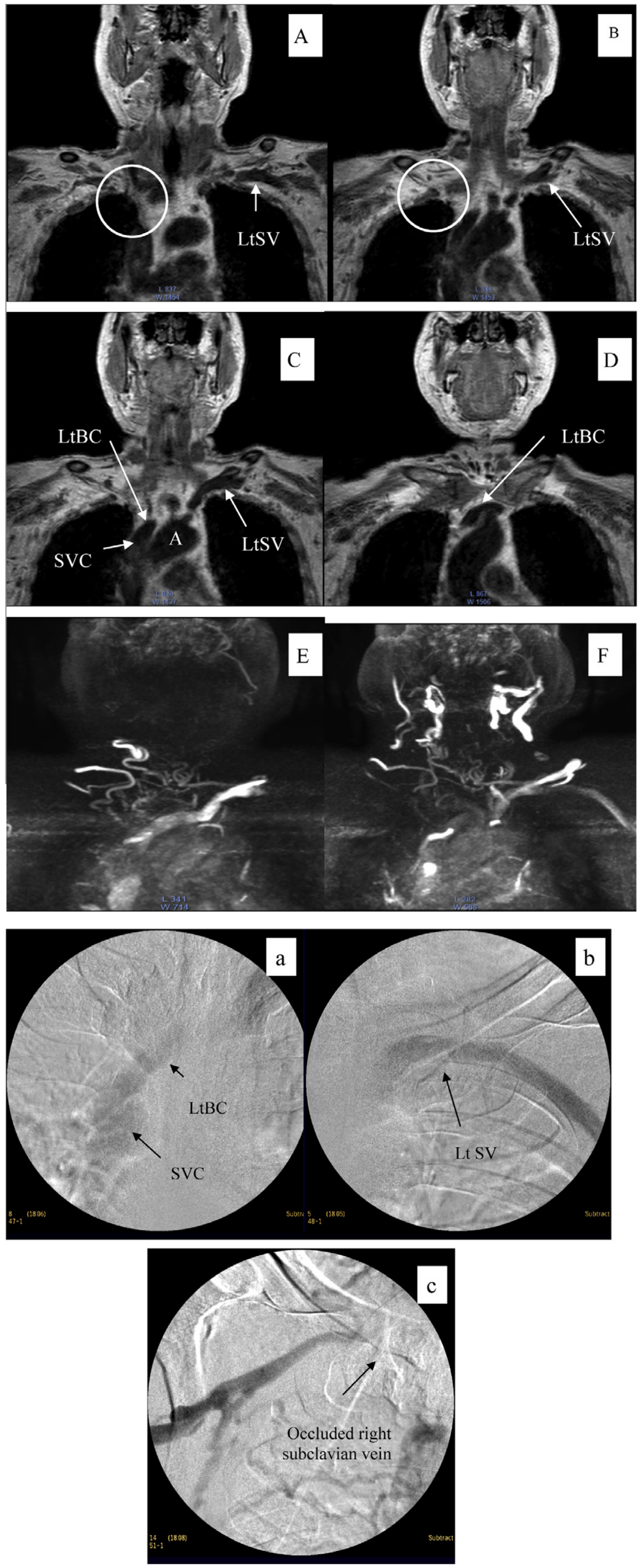

Fig. 3 Phase contrast MRV of male patient aged 75 years, with history of bilateral dialysis catheter insertion and failed access on right side seeking for dialysis access. (A–D) Source images of phase contrast MRV. (E and F) 3D reformate phase contrast MRV. Findings: Occluded right subclavian and right brachiocephalic veins (white circles) (A and B). Patent left subclavian vein (Lt SV) (A–C and F). Patent left brachiocephalic vein (LtBC) (D and E). And patent superior vena cava (SVC) (C). Aortic arch (A) (C and D). (a–c) DSV images. Findings: patent left subclavian vein, left brachiocephalic vein and SVC (a and b). Occluded right subclavian vein (c).

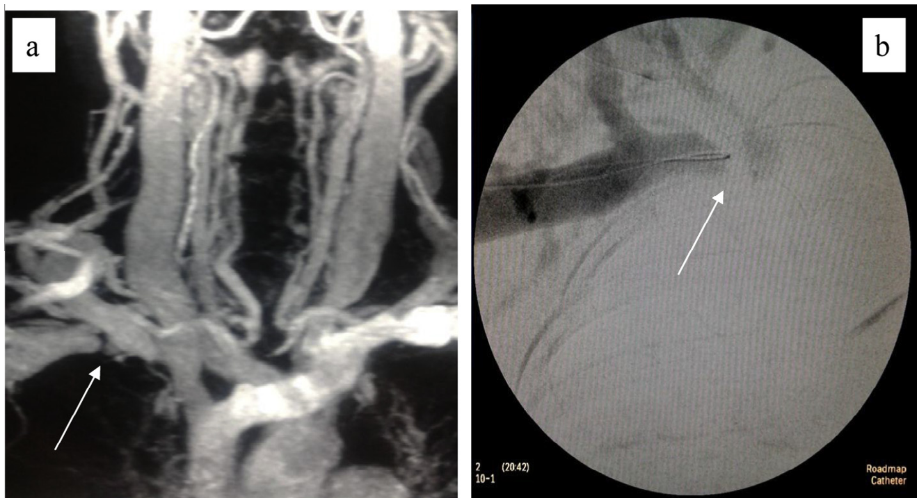

Fig. 4 (a) Dotarem enhanced MRV and (b) DSV image on the right side. Findings: total occlusion at the right subclavian vein (white arrow).

signs of anaphylaxis, and discharged on follow-up in the outpatient clinic for three months for any delayed complication.

Reconstruction of images was done by maximum intensity projections (MIPs) and multi-planar reformations (MPRs) using the standard software of the magnetic resonance unit. Resulted images describe examined veins whether they are patent, stenotic or occluded.

3.2.2. Digital subtraction venography

Digital subtraction venography (DSV) was conducted on all the 40 patients as the standard reference. An intravenous cannula was inserted at the veins of hand or forearm, 50 ml iodinated contrast was injected manually as rapid as possible (10 ml bolus at each run) and image acquisition was done through the mobile C-arm (BV pulsera; Philips Medical system, the Netherlands). There was difficult cannulation in 5 patients, so they were cannulated through the arteriovenous fistula to be examined on the affected side. The same procedure was repeated at the other side. The aim was to assess the patency of subclavian veins, brachiocephalic veins and superior vena cava, interpreted as patent, stenotic or totally occluded.

Immediately after examination, a hemodialysis session was arranged to each case, observed for 24 h for signs of anaphylaxis, and discharged on follow-up in the outpatient clinic for three months for any delayed complications.

Interpretation of the results was done separately by 2 independent radiologists (A Galal and M Abdel Latif), both had experience of 15 and 10 years respectively in MRV and DSV. They were blinded to the results of the other modality. Then the findings of the both modalities were correlated together as regards the ability to assess each vein. Interpretations of MRV were compared to interpretations of DSV.

3.2.3. Statistical analysis

Statistical analysis was carried out via Statistical package for social Science (SPSS) version 17 program on windows XP. Qualitative data were represented in the form of number and percentage. Kappa index with percent agreement between methods was calculated. Results were considered statistically significant if p value is less than or equal to 0.05.

4. Results

This study included 40 patients who were hemodialysis patients with suspected intrathoracic central venous stenosis.

Phase contrast (PC) MRV technique was done in 35 patients. The remaining 5 patients were uncooperative and examined by contrast enhanced MRV technique. All the 40 patients underwent DSV for comparison.

Comparison of the results of MRV and DSV showed that there was excellent agreement for diagnosis of normal (patent) and abnormal (stenosed or occluded) segments of all central veins. For patent, stenosed and occluded right IJV, $k = 0.93$, 1.00 and 0.86 and P value = <0.001, 0.023 and <0.001 respectively. MRV diagnosed all stenosed and occluded segments in right SCV with $k = 1.00$ and P value = <0.001 for diagnosis of patent, stenosed and occluded right SCV. For patent, stenosed and occluded right BCV, K = 1.00, 1.00 and 1.00 and P value = <0.001, 0.079 and <0.001 respectively. k was 1.00 and P value = <0.001 for diagnosis of patent and occluded left IJV, left SCV and SVC. For patent, stenosed and occluded left BCV, $k = 1.00$, 1.00 and 1.00 and P value = <0.001, 0.023 and 0.002 respectively.

The overall results showed excellent agreement as MRV detected 140 out of 141 patent, all 36 stenotic and 62 out of 64 occluded segments of intra-thoracic central veins with k were 1.00, 1.00 and 0.97 and P value = <0.001, 0.001 and 0.023 respectively (Table 1).

MRV diagnosed abnormalities of the intra-thoracic central veins with sensitivity = 98.6%, specificity = 100% and accuracy = 99.3% in diagnosis of patency and steno-occlusive disease of central veins (Table 2).

No significant complication caused by contrast in contrast-enhanced MRV studies.

5. Discussion

Detection of central veins stenosis has been a challenging issue; since the assessment of central veins of the chest is very difficult with sonography, MRV provides excellent assessment of

Fig. 5 Dotarem enhanced MRV. Findings: thrombosed right brachiocephalic vein and attenuated right internal jugular vein with patent right subclavian and superior vena cava. Patent left subclavian, left brachiocephalic veins. (a and b) DSV image. Findings: thrombosed right brachiocephalic vein with patent right subclavian (a). Patent left subclavian, left brachiocephalic veins (b).

Table 1 Comparison of the overall results of both MRV and DSV.

Category	MRV	DSV	K	95%CI	Percent agreement (%)	*P* value
Patent	140	141	1.00	0.87–1.00	100	< 0.001
Stenosed	36	36	1.00	0.44–1.00	100	0.001
Occluded	62	64	0.97	0.92–1.00	98.4	0.023
Not assessed	1	4				

subclavian vein, brachiocephalic vein, and superior vena cava (1).

Although CT venography is a reliable test it provides accurate and quick method in assessing the veins. The use of contrast materials beside the radiation exposure hazards limited its use in patients with renal impairment especially who are planning for access creation. While in MRV, the non-contrast technique renders its safe in renal impairment patients (9,10).

Digital subtraction venography remains the gold standard, but its use is limited also due to its invasive nature and radiation exposure risks (4).

All previous studies encouraged researchers to apply MRV in hemodialysis patients. Oxtoby et al. (11) used the contrast enhanced MRV to evaluate the patency of central veins on 17 patients using 1.0 Tesla MRI and injection of gadopentetate dimeglumine (Magnevist, Schering, Berlin, Germany), at a dose of 0.4 ml/kg body weight. The results showed that CE-MRV is a reliable diagnostic tool for the evaluation of patency of central veins. MRV successfully predicted an appropriate site in 10 patients for creation AVF. In the remaining 7 patients, MRV was valuable in confirming or excluding the clinical suspicion of central venous thrombosis. Kroencke et al. (4) published similar study on 16 patients clinically suspected with thrombosis in axillary and central veins. The image quality in MRV was good and the MRV did not miss any findings obtained by the gold standard DSV, color Doppler or CT studies. Shankar et al. (12) used phase contrast MRV techniques in 25 children underwent central venous catheter insertion. MRV results were superior to color Doppler ultrasound as regards accuracy, and to venography as regards less exposure to radiation hazards. MRV showed thrombosis of intra thoracic veins in 11 patients who had patent neck veins on ultrasound. MRV identified a patent vein for reinsertion of central venous catheter in 22 of 25 children. At operation, venous patency was confirmed in 20 patients (91% specificity).

In 2012, Gao et al. (1) used 3D contrast enhanced MRV using dimeglumine gadopentetate in the examination of 14 hemodialysis patients to detect stenosis in their central veins. The results were compared to those of DSV. MRV detected stenosis in central veins in 13 patients. In the last patient the results of MRV were inconclusive. Sensitivity of MRV reached 93%. No complication was reported from using contrast agent.

The results of our study were in agreement with the previous studies as the sensitivity, specificity and accuracy of MRV compared to DSV were 98.6%, 100% and 99.3% respectively in the diagnosis of patency and steno-occlusive disease of central veins.

Table 2 Sensitivity, specificity and accuracy of MRV in the detection of stenoocclusive disease of central veins.

	Sensitivity (95%CI)	Specificity	Accuracy	PPV	NPV
MRV	98.6% (97–98.6%)	100% (98.4–100%)	99.3% (97.7–99.3%)	100% (98.4–100%)	98.6% (97–98.6%)

Nephrogenic systemic fibrosis (NSF) is less likely to occur from gadoterate meglumine (Dotarem®) rather than other gadolinium based agents such as gadopentetate dimeglumine (magnevist®); Gordon (13) said that there are no reported cases of NSF after gadoterate meglumine (Dotarem®) injection. So, in our study, 5 patients who were critically ill and could not withstand the relatively long time examination of phase contrast MRV, were studied using the contrast enhanced MRV technique using the gadoterate meglumine (Dotarem®) as a contrast agent.

Noncontrast techniques such as phase contrast MRV provided another safe, noninvasive option in patients with renal impairment because no contrast is needed. However, Elkins and Alley (14) said that the difficulty we faced in phase contrast MRV was low image quality of the 3D reformats in partially occluded segments. In our study, we met this problem in three cases (case numbers 11, 15 and 16) who had stenotic segments in right SCV and right BCV, while the image quality in patients with patent veins was conclusive. This may be due to the stagnant flow in the partially occluded veins. We solved this problem by revising the 2D source images for occluded veins.

Elkins and Alley (14) found another difficulty was the long time of examination of phase contrast MRV that reached more than 6 min and the patient should be immobile all this period. This technique needs highly oriented, cooperative patients and the procedure should be fully explained to them. In the current study, we performed contrast enhanced technique which needs shorter time (23 s) in 5 uncooperative patients.

In this study, the quality of the images of CE MRV was higher than that of the phase contrast MRV. This is in agreement with Layer et al. (15) who confirmed that contrast-enhanced MRV has the advantage of high image quality as compared with phase contrast, as it has high signal to noise ratio. Also it has the advantage of increasing vascular signal and reducing background signal without risk of saturating slowly flowing blood. Contrast-enhanced vessels appear bright regardless of the presence of slow flow as the vascular signal can be further increased by using a small amount of contrast agent (Dotarem). Also it has the advantage of short examination time than phase contrast technique, so motion artifact is less with CE MRV than phase contrast technique. The disadvantage of CE MRV is that the data must be collected quickly while the contrast agent is still predominantly intra-venous. Also repeated acquisitions are not always possible because the contrast agent is rapidly distributed into the extra-vascular spaces, beside the high cost of the contrast.

The main difficulty we faced while performing DSV was dilution of the dye inside the veins as was reported by Kroencke et al. (4) who also concluded that MRV showed superiority in the assessment of internal jugular vein over the gold standard DSV; it was difficult in DSV to cannulate this vein especially when it was occluded. This is in agreement with our results, as MRV detected 14 cases with occlusion in internal jugular vein, while DSV detected only 12 cases.

Lastly, there was no reported hypersensitivity in all patients who underwent contrast enhanced MRV.

6. Conclusion

MR venography is a valuable technique for assessing intrathoracic central veins in regions inaccessible or poorly accessible to sonography. The noninvasive nature of MRV should make it preferable than DSV in the diagnosis of steno-occlusive disease of intrathoracic central veins in hemodialysis patients.

Conflict of Interest

The authors declare that there are no conflict of interests.

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